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“NATURAL CONTROL” OF WEEDS AND INSECTS BY FUNGI.

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“NATURAL CONTROL” is a shibboleth that has been much before the public in recent years, owing to the amount of prominence it has been given in the Press. The possibility of eliminating a weed or insect without direct labour or monetary expenditure has an especial appeal to the farmer or orchardist. The writer has of late received increasing numbers of specimens of weeds, insects, and the like, sent in by farmers and others to the Laboratory for examination, which were supposed to be killed by some “natural enemy.”

The possible value of fungi as controllants of weeds and insects has been held in view by the Department of Agriculture for many years; and since the writer commenced his duties as Mycologist in 1919 he has had to carry out much experimental and observational work in this connection. The present article brings together the results of this work.

FUNGI ATTACKING WEEDS.

Canadian Thistle (*Cnicus arvensis*).

A rust, *Puccinia obtegens*, which attacks this plant is perhaps one of the finest examples of the effects of control of any weed by a fungus. This organism has been present in New Zealand to the writer's knowledge for at least forty-six years (for specimens are in his herbarium collected in Canterbury in 1881 by T. Kirk), and is so widespread that it can be found in almost any clump of Canadian thistle. Once a patch becomes infected the disease persists for an indefinite period, and is noticeable for many years. One such clump of diseased thistle the writer noticed first in 1916, on the banks of the Turakina River, Wellington District, and on a visit this season it was found still to be infected. Once the rust becomes established it attacks a proportion of the plants, distorting them and so altering their colour as to render them conspicuous. Such plants fail to set seed (if female), as they usually succumb shortly after flowering. As has been mentioned, the disease is so widespread that scarcely a patch is free from it, whether in Auckland or Southland; yet Canadian thistle is spreading each year. The fact remains that only a proportion of the plants are infected, and although these are prevented from seeding, and usually killed, yet others in the clump reach maturity and produce more than sufficient seed necessary for perpetuation and spread.

The rust may be readily spread artificially; for all one has to do is to select a diseased stem, and, in the late spring during wet weather, thresh healthy plants with it. But even when this is carried out systematically, so that every individual plant in the patch is inoculated, at best not more than about 50 per cent. of the plants show

signs of the disease the following season (for it is in the season after inoculation that the disease distorts the plants). This matter has been discussed more fully by A. H. Cockayne (1, 2).

A second disease of Canadian thistle has become noticeable in recent years in certain areas through the North Island. This kills and blackens numbers of stems in certain patches. The writer's attention was drawn to such areas in the Gisborne district in 1922. Specimens were secured, and from these cultures were made and a species of *Fusarium* isolated. This was inoculated into Canadian-thistle plants grown in pots in the Laboratory, and in the majority of cases these were blackened and killed within three weeks. Numerous cultures were prepared and taken to Plimmerton, where patches of Canadian thistle were growing in rich land. Seven of these patches were selected, and a number of plants in each inoculated. In practically all cases the inoculated plants were killed, so that hopes were entertained that a useful controllant of the weed had been secured. Inspection the following year revealed the fact that not one of the inoculated patches showed the presence of the disease. Nor has it shown up subsequently either in these areas or apparently (for it has not since been recorded) in those at Gisborne from which the original material was secured. Stock cultures had been kept, and when the disease did not appear in the inoculated patches further experiments were conducted in the Laboratory with plants in pots. All were uniformly negative, so that at the time the fungus was considered to have lost its pathogenicity through long keeping. Specimens of the same disease have been sent in subsequently on numerous occasions, but, in view of the facts recorded above, further experiments with it have not been conducted.

A third disease of Canadian thistle has occasionally appeared. This disease, caused by the fungus *Sclerotinia sclerotiorum*, is readily noticeable in that it attacks the stem of the plant above ground-level and there produces a canker. The plant is killed, and if the stem is cut open, in the cavity will be found numerous black, shot-like bodies termed sclerotia, which serve to carry the disease from one season to the next, and also to characterize it. This disease has been noted on other weeds, such as spear thistle (*Cnicus lanceolatus*), wing thistle (*Carduus pycnocephalus*), and fennel (*Foeniculum vulgare*), and has proved troublesome on many cultivated flowers, potatoes, tomatoes, peas, beans, Jerusalem artichokes (largely grown for pig-feed), and many others. The writer has records of its occurrence on forty hosts in New Zealand.

In view of the fact that it has proved a serious trouble of cultivated plants, it was considered inadvisable to experiment with this disease. Moreover, it is doubtful if it would prove of any value as a controllant of weeds, for, despite the prevalence of the fungus throughout New Zealand, it has been found but once on each of the four weeds here enumerated as hosts.

Broom (*Cytisus scoparius*).

For the past six years the writer has had under observation a gully near the Biological Laboratory in which there is a dense growth of broom. About 1 per cent. of these plants are dead or dying, and over this period the percentage has not appeared to vary. Examination has shown that the organism killing the plants is *Stereum purpureum*,

the cause of silver-leaf of fruit-trees. This has proved one of the most serious diseases attacking fruit-trees in New Zealand (7, p. 284), and is also often troublesome on poplar, willow, white-birch, oleander, laburnum, lilac, tagasaste, &c. In view of this fact it is surprising that it has done so little damage to the broom in the gully referred to, as conditions are ideal for widespread infection, the plants being very numerous and close, and stock constantly pass through this area, breaking down branches and affording the wounds necessary for entry of the parasite. This is not an isolated case, for, as has been recorded elsewhere (7, p. 292), thousands of infected broom-plants are to be seen on waste land in the Tasman and Mapua districts of Nelson.

Gorse (*Ulex europaeus*).

Very frequently dead gorse-plants may be noted growing among healthy ones, and dead plants of this type are among those most frequently sent to the Laboratory for examination and report. Up to the present only one fungus has been isolated from such material. The work was conducted by Mr. J. C. Neill, Field Mycologist, who inoculated with the organism isolated (the fungus was not identified) seedling gorse-plants grown in pots, but all experiments were negative. Gorse is mentioned here (it being so frequently forwarded for examination) so that in future those interested will recognize the fact that, despite many attempts, only one fungus, and that not pathogenic, has been isolated from it. A satisfactory explanation for the frequent death of these plants is not forthcoming. Frequently examination has shown borer to be responsible; in other cases the plants have been found infested with cottony cushion scale (*Icerya Purchasi*), a pest known to kill this and other plants on occasions; but many other specimens have been examined in which neither borer nor scale was present.

Blackberry (*Rubus fruticosus*).

Owing to its economic importance, careful observations during the past five years have been made of the fungi present on blackberry.

The most outstanding instance of fungous attack upon this host occurred in 1922, and formed the subject of an article by the writer (4). In this instance it was reported in the Press that large areas of blackberry (many hundreds of acres) had been killed outright in Auckland Province. Mr. L. Paynter and the writer made a survey of the Ngawaro, Oropi, Tauranga, Waihi, Te Aroha, and Morrinsville districts, in which the disease was reported to be prevalent. As is usual on such occasions, the areas when examined were found to be small, ranging in extent from a few yards to about an acre.

The organism causing the death of these plants was isolated and found to be *Leptosphaeria Coniothyrium*, the cause of cane-wilt of raspberry. Inoculation experiments showed that, although this disease had killed numbers of plants in the field, it did but slight damage to the plants artificially infected, at best killing a few canes, but generally merely forming lesions on the latter. The following year the disease did not appear to do any damage in those areas where it was prevalent the previous season; and from that date it has not been reported as being of any moment. It is abundant on blackberry throughout New Zealand.

A second disease noted on the survey tour in 1922, and commented on in the same article, was a fruit-rot caused by the fungus *Rhizopus arrhizus*. Under favourable conditions this organism destroys most of the fruiting panicles of a plant—indeed, in one instance it was found to have destroyed most panicles over a considerable area in a swamp at Inglewood, Taranaki. Mr. R. Waters, Officer in Charge of the Biological Laboratory, recently brought in numerous specimens of these infected fruiting panicles. They were handed to Mr. N. R. Foy, Seed Analyst, who found that approximately only 1 per cent. of the seed from such panicles had matured an embryo. Thus it is seen that this disease under favourable conditions may almost completely destroy the seed. Unfortunately, these conditions are not readily attained, for it has been proved experimentally that this fungus attacks only overripe fruit, or fruit which has been injured in some manner. Further, it is essentially an organism which usually thrives only where the atmospheric humidity is high.

A third disease of blackberry abundant in New Zealand is leaf-spot, caused by the fungus *Septoria Rubi*. This produces spots on the leaves, but appears to have little detrimental effect on the host, as it is abundant wherever this plant occurs.

A fourth disease is caused by the rust *Kuehneola albida*, also common in most localities on blackberry. It attacks leaves and stems, but, apart from stunting the plant somewhat, does little damage.

The possibility of introducing fungus diseases of blackberry and related species of *Rubus* from abroad with a view to utilizing them as controllants has also been considered. Letters were sent to approximately fifty mycologists throughout the world, requesting information relative to any disease on *Rubus* spp., and that where any of these showed promise of being actively parasitic specimens and cultures should be supplied. Most replied that—apart from such diseases as cane-wilt and leaf-spot, which were already present in New Zealand—no diseases of any significance were present; a few regretted their inability to supply material; and three forwarded specimens. Dr. Pethybridge, England, forwarded viable material of the rust *Phragmidium violaceum* on blackberry; Dr. B. O. Dodge, Washington, D.C., U.S.A., forwarded the rust *Gymnoconia Peckiana*; and Dr. A. Sharples, Straits Settlements, forwarded cultures of three fungi from *Rubus* spp. All inoculations—which have been carried out over a period of twelve months—proved negative, save with the cultures from Dr. Sharples, which have given inconclusive and unsatisfactory results.

Bracken Fern (*Pteridium esculentum*) and **Hard Fern** (*Paesia scaberula*).

In 1919 Mr. E. Bruce Levy, Agrostologist, brought the writer abundant material of bracken which had apparently been killed by some disease. Cultures were made and a species of *Fusarium* isolated. This was inoculated into bracken-plants kept in pots in the Laboratory, but with negative results. Further inoculations were made into plants growing on the edge of a roadside near Weraroa: these also were negative. It was thought that if inoculations were carried out in the locality where Mr. Levy obtained the material better results might be obtained; consequently cultures were taken to Marton and seventeen

plants inoculated. Of these at a later inspection five were found to be dead, and the *Fusarium* was again isolated from the killed rhizomes. The following season an examination of the areas was made, but no dead plants could be found, nor have such appeared since.

Specimens since received from correspondents have sometimes yielded this same *Fusarium*, but more frequently no fungus has been isolated. In view of the indifferent results secured, further experiments with the *Fusarium* have not been undertaken.

Several times in recent years Mr. Levy has brought to the Laboratory specimens of hard fern apparently killed by some disease. This plant grows in patches, and in the centres of these areas frequently occur numerous dead plants. Among these, grasses usually become successfully established. Consequently Mr. Levy thought the possibility of securing a pathogen to kill similar areas on the class of country on which he had been working at Whangamomona would prove of considerable value. Unfortunately, up to the present no fungus or bacterium has been isolated from this hard-fern material.

Goat's-rue (*Galega officinalis*).

In 1919 Mr. J. Fleming, Stock Inspector at Palmerston North, brought to the writer diseased specimens of goat's-rue, which he found to be not uncommon on the banks of the Manawatu River at Palmerston North. The stems had been attacked at ground-level and destroyed, with the result that the plants had been killed.

Isolations were made and a fungus, *Phoma Galegae*, isolated. Cultures inoculated into young plants in pots were positive, the latter being killed in three weeks. Inoculations in the field were undertaken in the vicinity of the bridge at Palmerston North. Owing to the fact that the writer moved very shortly afterwards to Weraroa, the results were not followed up, but inspection of the area made six months later showed a number of dead plants. The disease did not appear to have spread, however, for no recently infected plants were found. The disease has subsequently been noted on several occasions on the riverbanks, isolated plants being affected; but in no instance can the disease be said to have proved instrumental in controlling the growth of goat's-rue in this region.

Tauhinu (*Cassinia leptophylla*).

In 1926 Mr. H. McDonald, Levin, reported to the Department of Agriculture that a disease appeared to be killing tauhinu on his property at Weraroa. The writer visited the area with Mr. McDonald and found a considerable number of dead and dying plants. Examination of infected plants showed they were being attacked by a wound parasite which penetrated through injuries formed as a result of the wind splitting branches at the crutches. Very many plants were examined, and on severely infected and dead plants numerous fructifications of one of the shelf-fungi were secured. These were sent to the Kew Herbarium for examination. Miss Wakefield, Mycologist at Kew, reported that the fungus resembled in general structure and spores resupinate forms of *Fomes ignarius*, but considered the colour of the flesh was not quite the same. No infection experiments with this

organism were undertaken, for the writer was informed that it was intended to use the organism commercially for the control of tauhinu.

Numerous other fungous diseases of weeds occur in New Zealand, but sufficient has been written to indicate that with our present knowledge it is not possible to destroy on a large scale any of the weeds listed by those fungi found attacking them. Sometimes in nature the severity of attack amounts to a local epidemic, but even were conditions governing such a severe attack known it is highly improbable that they could be artificially created over any extensive area.

FUNGI ATTACKING INSECTS.

Entomogenous fungi have been used for many years in the control of insects in the citrus-groves of Florida. Knowledge of this fact has led the writer to interest himself in this group.

Numerous instances of fungi attacking insects can be cited: For example, the well-known "vegetable caterpillars," which are not vegetables but larvæ of species of moths which have been parasitized by certain fungi; house-flies attached to a window-pane in the late autumn and surrounded by a "halo" of spores of the fungus *Empusa Muscae*; scale insects on leaves in the forest so altered as to be unrecognizable, &c.

One such fungus (*Cephalosporium Lecaniæ*) has been known for the past few years to attack the brown scale (*Saissetia oleæ*) in citrus-groves in the Auckland District. In fact, in certain seasons this fungus has become so widespread that it has frequently been difficult to find a scale not parasitized. Naturally, orchardists have been impressed with its value as a controllant of brown scale, and many inquiries have been made as to the best method of propagating it.

More recently Mr. Everett, Orchard Instructor, has forwarded from Tauranga another species (*Sphaerostilbe auranticola*) attacking red scale of citrus (*Chrysomphalus aurantiæ*). This organism also was abundant on all the scales on the specimen forwarded.

That such fungi should be used in the control of these scales seems practicable, and, as indicated, they are used for this purpose in Florida groves. Unfortunately, New Zealand experience has shown that they are unreliable, in that one season they may practically exterminate the scale in a locality, yet in the next may scarcely or not at all check the spread of these pests.

Experience elsewhere has been similar, for Mr. T. Petch (8), the world's authority to-day on this group of fungi, in a presidential address before the British Mycological Society in 1921, summarized the position as follows:—

At the present day, after thirty years' trial, there is no instance of the successful control of any insect by means of fungous parasites. If entomogenous fungi already exist in a given area, practically no artificial method of increasing their efficacy is possible. If they are not present, good may result from their introduction if local conditions are favourable to their growth; but, on the other hand, their absence would appear to indicate unfavourable conditions. It would seem that a fungus makes little progress until the insects are excessively numerous, either locally or generally, when for reasons not known an epidemic of fungous disease breaks out. And in this connection it may be noted that the apparently successful experiments in inducing a more rapid dissemination of an entomogenous fungus have usually been made during such an epidemic . . . The problem

which has yet to be solved by those who wish to control insects by means of fungi is how to create an epidemic at a time when such an epidemic would not occur naturally. The evidence indicates that it is not possible to accomplish that by the mere introduction of the fungus or by spraying spores from material or artificial cultures. The solution of the problem probably depends in each case upon a study of the bionomics of the insect.

This statement, from one so well qualified to discuss the subject, shows that at present the grower would be well advised to ignore attempts at control of citrus scale by the use of entomogenous fungi, and to rely upon the sprays recommended for the purpose.

Vast numbers of larvæ of insects are destroyed annually by the so-called "vegetable caterpillars." These fungi parasitize and replace the tissues of their hosts with a compacted web of mycelium. No less than six species are present in New Zealand (3, 5) — namely, *Isaria Sinclairii* (Berk.) T. Petch, on specimens of cicada, *Melampsalta cingulata* Fabr. and *M. cruentata* Fabr.; *Cordyceps Craigii* Lloyd, *C. consumpta* G. H. Cunn., and *C. Robertsii* Hook., on larvæ of *Porina* spp. (subterranean grass-caterpillars); *C. Aemonae* Lloyd, on the larvæ of *Aemona hirta* Fabr. (flat-headed lemon-tree borer); and *C. Kirkii* G. H. Cunn., on *Deinacrida rugosa* Buller (Stephen Island weta). Some of these fungi are rare, but others—e.g., *Cordyceps Robertsii* (the common "vegetable caterpillar")—are abundant and collected in their hundreds in certain localities such as Mount Egmont and the Rotorua district.

Flies parasitized by a fungus, *Empusa Muscae*, are familiar to all in late autumn in dwellings, yet flies appear as abundant as ever the following season.

A fungus, a Phycomycete, species unknown, was in 1919 at Weraroa found to have almost exterminated the larvæ of diamond-back moth (*Plutella maculipennis*) attacking the swede crops on the Central Development Farm. This proved so promising that field observations over a period were carried out. On all the hundreds of leaves examined numerous larvæ were present, but in all cases these were found to be parasitized. The fungus was isolated by Mr. R. Waters, but, as living larvæ could not be obtained (so widespread had the parasite become), he was not able to carry out inoculation experiments. The following season observations made on the farm and in the district showed that, although the diamond-back moth was abundant, traces only of the parasite were present; nor has it been observed to be prevalent subsequently in any part of New Zealand, though examinations have been conducted each year.

In 1923 Mr. D. Miller, Entomologist, brought the writer numerous specimens of codlin-moth (*Cydia pomonella*) larvæ from Canterbury parasitized by a species of fungus. Only the *Isarial* form was present, and identification was thus not possible. So abundant was this parasite that Mr. Miller had difficulty in obtaining unaffected larvæ. Nevertheless codlin-moth was as troublesome as ever the following season.

These facts bring home forcibly the truth of Mr. Petch's remarks. We know so little at present regarding that balance between casual parasitism and extermination of any one host by its parasite that, until the conditions governing such can be worked out and controlled, control of insect pests by fungi must be regarded as possessing practically no value.

FUNGI ATTACKING FUNGI.

Even fungi have their parasites, as is well known by the very numerous examples which have been recorded at intervals in mycological literature. A few examples must here suffice. One frequently finds present in the uredosori of many of the rusts the fungus *Darluca filum*. This parasite destroys the uredospores, and also on occasion attacks in addition aecidiospores and teleutospores. So widespread is this parasite that we frequently have difficulty in securing specimens free from it. In a recent paper (6) the writer has recorded it as being found on no less than twenty-eight species, and it appears to be equally abundant throughout the world. It might be expected that such a parasite would be of material value in checking the spread of many of these rusts. Unfortunately, such is not the case, for examination of any rust pustule shows that as a rule a small proportion only of the spores have been destroyed, this number being usually in the vicinity of 1 per cent., and seldom more than 5 per cent.

Other parasites of a similar type have been noticed in New Zealand from time to time, such as *Cicinnobolus Cesatii*, on powdery-mildew of the apple; *Tuberculina persicina*, on certain rusts; and a *Fusarium* (unidentified), on the uredosori of acacia gall-fungus (*Uromycladium notabile*). But in no instance have they proved of any value in checking the spread of these diseases.

CONCLUSION.

From the foregoing data, collected during the past eight years, dealing with numerous diseases of weeds and insects under varying climatic and soil conditions, only one conclusion can be drawn—namely, that with our present knowledge and technique it is not possible to use in the economic control of weeds and insects fungi which occasionally attack them under natural conditions. This is to be regretted, for such a method of control would have proved of inestimable value, especially in those areas and on those properties where the labour of eradication by hand is too costly.

The evidence produced indicates that it is but a waste of time to proceed with experiments along these lines. It also presents the fact that the Department of Agriculture has for many years given attention to the investigation of any such possible methods of weed or insect control.

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